TRANSFER OF LEARNING

STANFORD UNIVERSITY LIBRARY 1929

BY CHARLES W. BRAY

A DISSERTATION
PRESENTED TO THE FACULTY OF PRINCETON UNIVERSITY
IN CANDIDACY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

STANFORD UNIVERSITY LIBRARIES
IN CHORAGIC

Offprinted from JOURNAL OF EXPERIMENTAL PSYCHOLOGY, Vol. XI, No. 6,
December, 1928.

3781
P95B
UNCLASSED

Offprinted from JOURNAL OF EXPERIMENTAL PSYCHOLOGY, Vol. XI., No. 6, Dec., 1928

TRANSFER OF LEARNING

BY CHARLES W. BRAY

Princeton University [1]

It has long been known that practice of one part of the body in performing a skilled act increases the ability of the bilaterally symmetrical part in the same act. The effects of practice are transferred from one hand or one arm to the other, and from one toe to the similar toe of the other foot. This phenomenon has been called cross-education.[2] There are also indications that a similar transfer takes place to all parts of the body, not merely to bilaterally symmetrical parts. The experiments to be reported here were designed to study the transfer of learning from one limb to any other.

Bilateral transfer or cross-education was first noticed by Weber. In a letter to Fechner[3] he described the activities of his son, who was a spontaneous mirror writer, using his left hand in reversed fashion, although he had been taught to write only with the right hand. Weber concluded that in training the right hand, the left had been trained simultaneously to make symmetrical movements. Fechner reported a similar observation on himself. In the course of one of his investigations, he had frequent occasion to write the figure 9 with his left hand; then he found that when he used the right hand again he reversed the figure mirrorwise. A related phenomenon was discovered at the same time by Volkmann.[4] In an investigation on the two-point limen, he found that practicing the left arm in the discrimination of two points helped the right arm to make the discrimination. Further work showed that practice effects were transferred to symmetrical parts and to parts related in function but not to the rest of the body. These observations were later extended by numerous investigations into the subject. Scripture, Smith and Brown (pp. 114–119) devised an experiment to show transfer from right to left hand of the ability to thrust a needle into a small

---

[1] This study was carried out at the Psychological Laboratory of Princeton University.

[2] E. W. Scripture, T. L. Smith and E. M. Brown, On the education of muscular control and power, *Stud. Yale Psychol. Lab.*, 1894, 2, 115.

[3] G. T. Fechner, Beobachtungen, welche zu beweisen scheinen, dass durch die Uebung der Glieder der einen Seite die der andern zugleich mitgeübt werden, *Ber. d. sächs. Gesell. d. Wiss., math. phys. Cl.*, 1858, 10, 70. (Reviewed by W. W. Davis, Researches in cross-education, *Stud. Yale Psychol. Lab.*, 1898, 6, 6.)

[4] A. W. Volkmann, Ueber den Einfluss der Uebung auf das Erkennen raümlicher Distanzen, *Ber. d. sächs. Gesell. d. Wiss., math. phys. Cl.*, 1858, 10, 38. (Reviewed by Davis, *op. cit.*)

hole without touching the sides of the hole. They first made a test of the left hand in this act and then practiced the right hand. A re-test of the ability of the left hand showed that it had improved 26 per cent. In the same way, they found that practice by the right hand in pressing a dynamometer resulted in a gain of strength of the left hand. Their method has been followed in numerous later experiments. It consists in making two tests of some part of the body and interposing a period of practice by some other part. The difference between the first and last tests is assumed to show the transferred improvement. Unfortunately the method fails to consider the effect of the first test upon the second. Acts of skill are known to improve greatly in the first few trials; so it is only to be expected that the second test will show an improvement over the first. For this reason the method described above gives no adequate measure of transfer. This defect was pointed out by P. H. Ewert,[5] who has shown that early estimates of the amount of transfer must be considerably discounted, and that a different method must be followed.

The defect in the method does not, however, completely invalidate the early work on transfer. Frequently it was found that the unpracticed part gained on its second trial as much as the practiced part gained in many trials. Thus in the work of Scripture, Smith and Brown it was shown that the effect of ten-days practice with the right hand caused an improvement in the left equal to the improvement shown in four days by the right. This seems fair evidence for the existence of transfer, although no measure of the amount can be so gained.

Following Scripture numerous experiments have been devised to show cross-education in skill, sensory education, fatigue and strength. In skill, Davis[6] found that practice of the right great toe in speed of tapping was shared to some extent by the left great toe and that accuracy in hitting at a mark with a fencer's foil was transferred from right to left arms. Woodworth[7] has shown that training in making accurate movements transfers from left hand to right when the training is successful. Unsuccessful training has no cross-effect. Other studies have shown cross-education in mirror drawing,[8] in juggling,[9] in ability to use a typewriter,[10] and, finally, in ability to set numbers in an adding machine.[11] In the field of sensory education several studies have been made of transfer. Dresslar[12] has repeated and confirmed the work of

---

[5] P. H. Ewert, Bilateral transfer in mirror drawing, *Ped. Sem.*, 1926, 33, 235–249.

[6] W. W. Davis, Researches in cross-education, *Stud. Yale Psychol. Lab.*, 1898, 6, 6–50.

[7] R. S. Woodworth, The accuracy of voluntary movement, *Psychol. Rev. Monog. Suppl.*, 1899, 3, (no. 13), 105 f.

[8] D. Starch, A demonstration of the trial and error method of learning, *Psychol. Bull.*, 1910, 7, 20–23; L. L. Henderson, The psychology of learning, (Bachelor's Thesis, 1906; deposited in the Library, Univ. of Wisconsin); H. S. Hill, Minor studies in learning and relearning, *J. Educ. Psychol.*, 1914, 5, 375–386; P. H. Ewert, *op. cit.*, 235–249.

[9] E. J. Swift, Studies in the psychology and physiology of learning, *Amer. J. Psychol.*, 1903, 14, 201–220.

[10] W. Frankfurther, Arbeitsversuche an der Schreibmaschine, *Psychol. Arb.*, 1914, 6, 419; A. Langelüddecke, Untersuchungen über die Vorgänge beim Erlernen des Maschinesschreibens unter normalen und krankhaften Bedingungen, *Psychol. Arb.*, 1923–25, 8, 304–414.

[11] W. H. Norcross, Experiments on the transfer of training, *J. Comp. Psychol.*, 1921, 1, 317–364.

[12] F. B. Dresslar, Studies in touch, *Amer. J. Psychol.*, 1894, 6, 324–330.

Volkmann on transfer in tactual discrimination. Experiments on the conditioned reflex show a similar phenomenon. Anrep [13] has found that scratch stimuli on either side of the body are equivalent in calling out salivary secretion; although only one side of the body has been used in establishing the conditioned reflex. Cross-effects in sensory processes do not always occur, however, for one author [14] finds that adaptation to weights is not transferred from one hand to the other.

Experiments on the transfer of fatigue give somewhat ambiguous results, for cross-effects can be both positive and negative. Bryan,[15] by testing the rate of tapping from various joints, found crossed fatigue effects, independent of any general bodily fatigue. Peculiarly enough, however, one subject showed an opposite cross effect, that is, the fatigue of one joint caused an increase in the rate of the same joint of the other side. This result is confirmed by Joteyko,[16] who likewise finds positive and negative cross-effects in fatigue. The nature of the transfer seems to be constant in any one individual.

Transfer of strength has been shown by Davis who found that the left arm gained in girth, strength (as measured by a dynamometer) and endurance by exercise of the right arm in swinging a dumbbell, pressing a dynamometer or pulling an ergograph.[17] Similar results are shown by Wissler and Richardson.[18]

The defect in method as noted above has been remedied by Ewert in mirror drawing. Ewert used two groups of subjects, one of which followed the usual procedure. The other group acted as controls, receiving only the end-tests of the unpracticed part. Comparison of the relative improvement of the two groups gives an adequate measure of transfer. Ewert found that the non-preferred hand improved 36 per cent. in time and 21 per cent. in errors by fifty-trials practice with the preferred hand. Measured in the old way the transfer would have been estimated at 82 per cent. in time and 76 per cent. in errors. This shows that previous estimates of transfer have been too high, but that some transfer actually occurs. Ewert was also able to show that transfer is greater from the preferred to the non-preferred hand than in the opposite direction.[19]

There are some indications that transfer takes place to parts other than those bilaterally symmetrical. As mentioned above, in the two-point limen Volkmann found that parts related in function shared in the practice of one finger; *i.e.*, other fingers shared in the practice but the arm did not. Other investigators have obtained similar results. Davis [20] found that practice in speed of tapping the right great toe was shared by the index fingers of both hands. The left index finger gained almost as

---

[13] G. V. Anrep, Irradiation of conditioned reflexes, *Proc. Roy. Soc. Lond.*, 1922–23, 94B, 409.

[14] L. Steffens, Ueber die motorische Einstellung, *Zsch. f. Psychol. u. Physiol. d. Sinnesorg.*, 1900, 23, 241–265.

[15] W. L. Bryan, Voluntary motor ability, *Amer. J. Psychol.*, 1892–93, 5, 149.

[16] J. Joteyko, Participation des centres nerveux dans les phénomènes de fatigue musculaire, *Année psychol.*, 1900, 7, 161–165.

[17] W. W. Davis, Researches in cross-education, *Stud. Yale Psychol. Lab.*, 1898, 6, 18–29; 1900, 8, 64–109.

[18] C. Wissler & W. W. Richardson, Diffusion of the motor impulse, *Psychol. Rev.*, 1900, 7, 34.

[19] *Ped. Sem.*, 1926, 33, 235–249.

[20] W. W. Davis, Researches in cross-education, *Stud. Yale Psychol. Lab.*, 1898, 6, 6–50.

much as the part practiced while the right showed a slightly smaller improvement. The validity of this distinction between fingers is questionable, for Davis had no control-subjects and the difference was small.

Lashley [21] also noted transfer-effects in the course of work on cerebral function in learning. He taught monkeys to open a problem box with the right hand. He then destroyed the motor area of the left cortex, thus paralyzing the right hand. When the animals were again placed in front of the problem box, they used the left hand, the feet and sometimes the head to open it. The animals were said to show little or no random movement in using these previously unpracticed parts. In one case transfer to the left arm occurred although it had been temporarily paralyzed during learning by the right.

Theory of Transfer. Several types of explanation have been proposed to account for transfer from one part of the body to others. The early investigators found an explanation in terms of the improvement of some faculty.

Davis, for example, concluded that training the attention and will-power explained in part the transfer of ability to tap rapidly (p. 49). Scripture [22] finds that training the will-power explains crossed gains in strength. Explanation by faculties is no longer acceptable in psychology, for it is a purely verbal explanation. Furthermore, investigations of the doctrine of formal discipline militate against the faculty explanation.

Other explanations of cross-education and transfer from one part of the body to others have been drawn from the related field of transfer from one situation to another. The voluminous work on this subject has led to two theories, that of *identical elements* and that of *generalization*, both of which seem applicable to the type of transfer considered here. The theory of identical elements would say that transfer from one part of the body to another takes place where the subject learns part-activities involved in the performances of both members. Thus Woodworth [23] suggests that common head, eye or trunk movements may be involved in the performance of an act of skill or strength by either hand.

The theory of generalization does not differ greatly from that of identical elements except that it emphasizes conscious rather than behavioral factors. It suggests that transfer is due to the generalization of methods, attitudes or ideals learned in practice by one part of the body and applied to the performance of the act by other parts. This type of explanation is used by Swift [24] in his work on transfer of ability to juggle two balls. He found that methods of handling the balls, of throwing them, and of recovering from bad throws were developed by one hand and then carried over to the other.

The two theories are more or less complementary. They can therefore be combined and called the theory of *common elements*.[25] There seems to have been only

---

[21] K. S. Lashley, Studies of cerebral function in learning, *Arch. Neur. & Psychiat.*, 1924, 12, 249–276.

[22] E. W. Scripture, Recent investigations at the Yale Laboratory, *Psychol. Rev.*, 1899, 6, 165.

[23] R. S. Woodworth, *Le mouvement*, Paris, 1903, 325.

[24] E. J. Swift, Studies in the psychology and physiology of learning, *Amer. J. Psychol.*, 1903, 14, 201–220.

[25] J. V. Breitwieser, *Psychological education*, N. Y., 1926, 164.

one effort to isolate experimentally common elements of method or behavior and to determine to what extent they play a part in transfer. Norcross, in his work on bilateral transfer of ability to place numbers in an adding machine, tried to isolate common elements, such as ability to read quickly and accurately the numbers to be listed, familiarity with the keyboard, actual use of the keyboard apart from the setting of the experiment, etc. He found that practice with any of these part processes alone acted favorably on ability to perform the act as a whole. Unfortunately Norcross [26] did not use many subjects. As his data show a large individual variability, his results are not necessarily conclusive evidence for the theory of identical elements. It is further to be regretted that he used no control subjects, for the gains reported (from 7% to 48%) might easily be due to practice rather than to transfer.

One further possibility has been advanced to explain transfer. Davis suggests (p. 49) that there may be some actual training of the so-called unpracticed part. This might take place, he suggests, by a spread of the nervous impulse to the motor centers governing the unused part, or by spread of the impulse to the muscles themselves, so that the apparently unused part might actually receive practice. The same possibility is advanced by Woodworth, who says, "L'exercise d'une main n'est pas entièrement séparé de celui de l'autre; les mains sont souvent innervées ensemble et donc entraînées spécifiquement en meme temps" (p. 325).

There is a wide variety of evidence showing the close relationship between the parts of the body, especially between the two sides. It is known, for example, that injuries to the left side of the cortex disturb skilled acts performed by either side of the body.[27] And in cases of hemiplegia a paralyzed arm may be made to move by movement of the normal arm. These movements are frequently symmetrical to those of the normal arm.[28] Observations of this sort show the close relationship between different parts of the body. There has been no evidence advanced, however, to show that associated movements of the so-called unused part are of any importance in transfer.

To summarize:—There are current two theories of transfer; the theory of common elements and the theory which assumes some sort of practice of the apparently unused member. It is one of the aims of this investigation to furnish experimental data, which may throw light on the relative validity of these two theories.

The Experiments

In order to study transfer from one part of the body to others, mirror drawing was chosen as a task. The procedure for the hands followed that described by Dearborn [29] and used by Starch and Ewert. The subject traces the outline

[26] W. H. Norcross, *op. cit.*

[27] H. Liepmann, Die linke Hemisphäre und das Handeln, *Münch. med. Woch.*, 1905, 48. (Reviewed in *J. f. Psychol. u. Neur.*, 1906, 7, 190.)

[28] F. M. R. Walsche, On certain tonic or postural reflexes in hemiplegia with special reference to the so-called associated movements, *Brain*, 1923, 46, 136.

[29] W. F. Dearborn, Experiments in learning, *J. Educ. Psychol.*, 1910, 1, 374–378.

of a star which he can see only through a mirror. An effort was made so to adapt the experiment that the task could be performed by the feet as well as by the hands. The technical difficulties as well as the difficulty of the task prevented the attempt to obtain transfer from hands to feet; but the impression of the experimenter and that of the subjects as well was that the feet gained considerably from the practice of the hands. Transfer from right to left hand was shown by the results; but because of certain errors in the procedure this work was unsatisfactory. The results confirmed, in general, those of Ewert on transfer from preferred to non-preferred hand.

It seemed to be desirable to obtain a method by which transfer from hand to foot could be adequately studied. For this purpose a new experiment was undertaken which involved a combination of two old experiments on the acquisition of skill, namely a mirror-experiment and an accuracy-experiment. The task set the subjects was to hit at a target seen indirectly through a mirror.

The subject sat at a table placed against a wall. Mounted on the wall was the target, consisting of a cross drawn on a sheet of white paper, 8 x 11 inches in size. Direct view of the target was prevented by a wooden screen, set above the table and directly in front of the subject. At the subject's left was a mirror placed at right angles to the wall. By means of the mirror an indirect view of the target could be obtained. The subject, holding a pencil in his hand, placed his arm under the screen with his elbow resting on a spot marked on the table. This spot was directly in front of the center of the cross. The arm was held upright and in such a position that the back of the pencil touched the screen. The subject, looking into the mirror, hit at the target, with the purpose of coming as close to the center of the cross as possible. After hitting he brought his arm back to the starting position, so that the pencil again touched the screen. Then he hit again at the target, trying to correct any previous error. The arm was again brought back to the starting position and the procedure repeated. The speed of hitting was controlled by a metronome beating at 72 per minute. On one beat the subject hit forward, on the next he returned to the starting position, and so on. By having the subject hit in time to the metronome and by having him return to the screen after every hit, both the speed and the amplitude of hitting were controlled. After ten successive hits the subject was told to stop and was given a rest period of two minutes. A new target was then placed on the wall and the procedure repeated.

For practice with the foot a similar procedure was used. The subject sat in an elevated chair with his thigh in a rest. This rest was directly in front of the target, so that the foot hung in front of the mark. The target was obscured by a screen, but on the left was a mirror in which it could be seen indirectly. A pencil was securely

attached to a light block of wood, which was strapped firmly to the subject's foot. By this means the subject could hit at the target and leave a mark on it. Speed and amplitude of hitting were controlled in the same manner as above. Typewritten instructions were given to the subjects.

> The object of this experiment is to hit several times in succession at the center of the cross you see in the mirror. The hitting is to be done in time to the metronome, which beats one stroke for the forward movement and one for the backward. After the forward movement return always until you hit the board in back of your hand (foot). In hitting try not to hesitate but hit with one single jab.
>
> After a certain number of trials you will be told to stop and there will be a short intermission. During each of these intermissions please give a report of your experience during the test, noting methods, if any are used, confusion due to the necessity for timing the hits, or anything important to the experiment. Try not to let this report interfere with your attention to the experiment, however. Make it retrospective. Remember particularly these points:—
>
> Each hit is to be a single jab at the mark.
>
> Keep in time to the metronome.
>
> Hit the board in back of your hand on the backstroke.

The experimenter had at his disposal the sheets of paper on each of which were ten pencil marks representing the subject's efforts for that trial. Each set of ten hits was called a trial. The average distance of the ten hits from the center of the cross gave a measure of the subject's accuracy on that trial. This distance was obtained by laying the sheets of paper over a sheet of graph paper, ruled in 2-mm squares and illuminated from below. The distance of each hit could be determined by counting the number of squares between it and the target, in the horizontal direction. By means of the graph paper a convenient and accurate method of measuring the performance of the subject was obtained.

It was decided to eliminate the preliminary test of the unpracticed member, as a test of this sort makes it impossible to determine the effect of transferred practice on the first trial with the unpracticed part. It was furthermore desirable to determine the effect of transferred practice on later trials with the new part. Consequently a measure of transfer was obtained by using two groups of subjects, one of which received practice with one part of the body, followed by practice with another part, while the other group received only practice with the latter. In the preliminary experiment undertaken here, one group of four subjects received 60 trials on the right hand followed by 40 trials with the right foot. The other group of four subjects received 40 trials with the right foot. Comparing the records of the two groups on the foot gave a measure of the effect of the hand-practice on the performance of the foot.

A considerable difference between the two groups was found. The effect of the previous practice with the hand was to decrease considerably the amount of the initial error of the transfer subjects. At the beginning of practice there was a large difference between the two groups. This difference decreased considerably with successive practice. Because of the small size of the two groups no definite conclusions could be drawn; but it was felt that an adequate method of studying transfer had been found. For further work it was thought best, however, to simplify the experiment by making the target a simple vertical line instead of a cross. The mirror reverses in the horizontal direction only and to study the transfer of a mirror coördination it is best to limit the practice to that form of coördination alone.

The target, then, was changed to a simple vertical line, bisecting the sheet of paper. The instructions were changed to meet this new condition. They also emphasized more strongly the necessity for accuracy and cautioned the subjects against practicing between experimental periods or talking about the experiment with other subjects.

Transfer from Hand to Foot

Two new groups of subjects were obtained for the changed experimental conditions. Group I (14 Ss) was given sixty trials

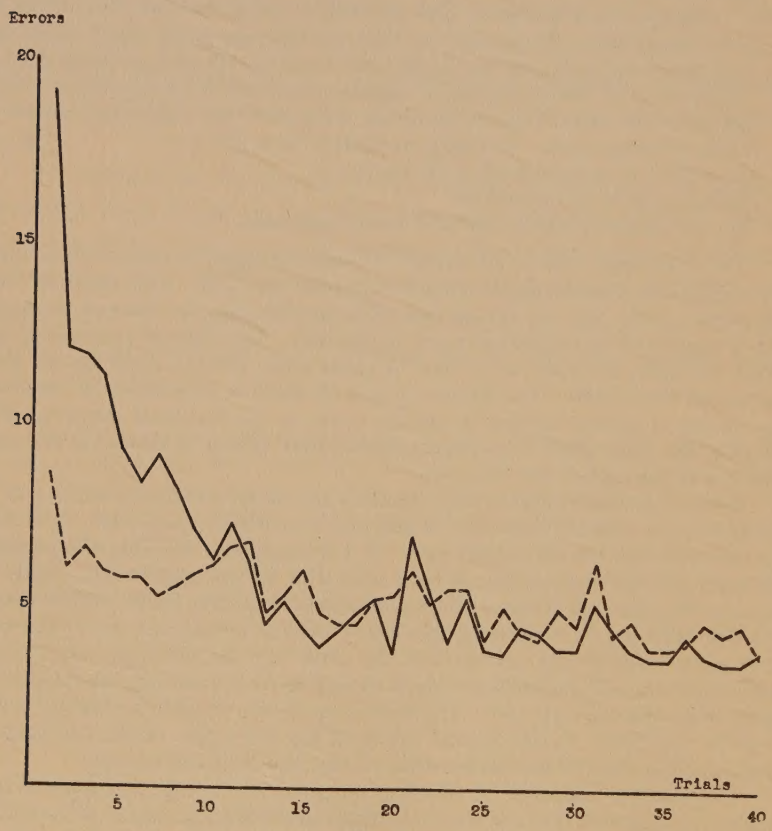

FIG. 1
——— Group 1
——— Group 2

practice with the right hand followed by forty trials practice with the right foot. Ten trials were given in one sitting and with a few exceptions sittings were given on successive days.

Group II (14 Ss) received forty trials with the right foot. It should be mentioned that in these, as in all groups to follow, only right-handed subjects were used.

The average foot-records of the two groups are compared in Figure 1. They reveal a typical learning curve for Group II, in this case the control group. There is a high initial error, which decreases fairly rapidly in the first few trials, but with slow improvement after the first ten trials. Group I, the transfer group, shows a very different curve; a small initial error, a large fall from the first to the second trials and a period of slow improvement thereafter. The curves of the two groups meet and remain the same after the tenth trial. The initial error of the transfer group is approximately equivalent to that made by the control group on the sixth trial. The transfer group, therefore, has saved the equivalent of about six trials by reason of its previous practice with the hand.

The differences between the two groups are statistically significant. It was found that the difference on the first trial was over seven times its P.E. For the first four trials the differences are more than four times their probable errors, indicating that the differences on these trials are not due to chance. After the fourth trial the differences are less than four times their probable errors, the statistical significance decreasing with the size of the difference.

Group I, the transfer group, had received a large amount of practice on the hand. In order to ascertain the effect of decreasing the amount of hand-practice, two new groups were obtained. Group III (11 Ss) was given 20 trials practice with the right hand, followed by practice with the foot. Group IV (12 Ss) 10 trials practice with the hand, followed by the foot. Comparing the averages of these two groups on the foot with that of Group I shows the effect of 60, 20, and 10 trials practice with the hand on the subsequent practice with the foot. The averages for the three groups are shown in Figure 2.

There are practically no differences between the three groups. With the exception of a few small variations the

three curves are the same throughout.[30] Varying the amount of hand-practice from ten to sixty trials has no effect on transfer of learning to the foot. This means that the slight improvement characteristic of the hand-practice after the first

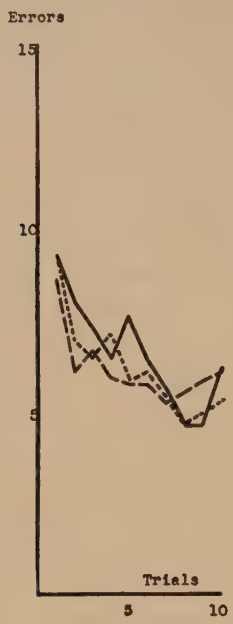

FIG. 2

——— Group 1
——— Group 3
- - - - - Group 4

ten trials is not transferred, or at least, that it has no observable effect in this experiment.

A study of the individual curves of Groups III and IV reveals an interesting and important fact. In these groups the majority of the Ss show very little if any improvement on the foot after the first two or three trials. They show a small

[30] This statement holds true only after one subject of Group III has been thrown out on the second and third trials. On these two trials this S was extremely poor, but he returned to about average in a few trials. On the second and third, he seemed to suffer a breakdown, lost all control over himself and appeared very embarrassed and self-conscious. Inclusion of his record on these two trials would distort the results of the rest of the group.

initial error and very little, if any, improvement. That is, they have almost nothing to learn. A few Ss, however, (a total of five in the two groups) show a large initial error and improve relatively slowly. Their curves are quite like the curve for Group II, the control group. Examination of the hand-records of these individuals shows that in every case either no improvement had been made on the hand or that the stage of slow improvement had not been reached when the hand-practice was discontinued. In all other Ss of these two groups the first drop in the learning curve of the hand had been completed and the secondary stage of slow improvement had been started when hand-practice was discontinued. For these latter Ss, curves for the foot typically like that for the average of the transfer group were obtained. It would seem that unless those adjustments which cause the first drop in the learning curve of the hand have been completed, no transfer takes place. Furthermore, these results show that the slow, gradual improvement, characteristic of the later periods of hand learning, has no observable effect on the foot.

Transfer from Foot to Hand

In order to study transfer from foot to hand it was only necessary to give Group II practice with the right hand following its practice with the foot. Group II, therefore, was given 40 trials with the right hand following practice with the right foot. Comparison of its record on the hand with that of Group I gives the effect of previous practice with the foot upon the performance of the hand.

The averages of Group I and II on the right hand are shown in Figure 3. There is a slight difference in favor of Group II, which is, in this case, the transfer group. Although the difference is not great it is quite constant and lasts throughout the practice. The differences are not significantly greater than their probable errors. Consequently the question is raised whether the difference between the two groups is the result of transferred learning or whether it is not the result of a chance difference in ability between the two groups. In the work on transfer from hand to foot, trans-

fer was only effective in the first part of learning. Likewise experiments on transfer from one situation to another have shown that transfer is effective only in the first stages of learning. When a rat, *e.g.*, has learned to run one maze, the

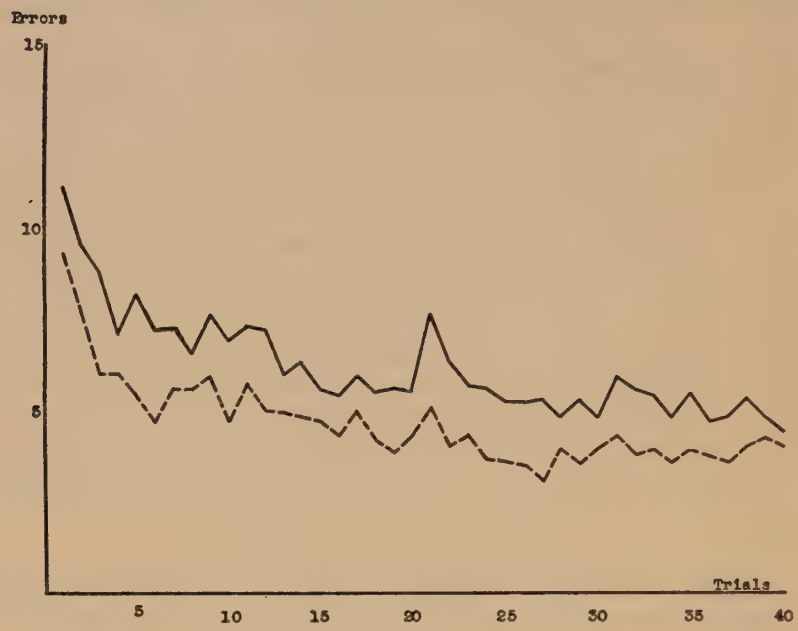

FIG. 3

——— Group 1
— — — Group 2

training affects the first stages but not the later stages of learning a subsequent maze.[31] These facts would indicate that the results of the present experiment are due to chance rather than to transfer.

On the other hand, there is a possibility that transfer from foot to hand occurs but is obscured by a certain factor. During the hand-practice it was observed that the hand frequently changed position with respect to the arm while the subjects were hitting. In the great majority of subjects the change bore no relation to corrections but appeared to be a

[31] L. W. Webb, Transfer of training and retroaction, *Psychol. Monog.*, 1917, 24, (no. 104).

chance affair. The phenomenon was occasionally reported by subjects as a source of error that they found impossible to control. The hand could not be kept in a constant position with relation to the arm. This introduced chance errors into the experiment, and it was thought that a chance error of this sort might serve to mask transfer effects. Accordingly a new experiment was devised in an attempt to rule out this factor.

The pencil was attached to a light piece of wood ten inches in length. On one end of the device a rounded block of wood was placed, which could be grasped comfortably by the hand. When held in the hand, the strip of wood extended nearly to the elbow, being strapped to the arm in two places. By means of this device, the wrist and hand were prevented from moving except in connection with movements of the whole arm, and the above mentioned source of error was eliminated.

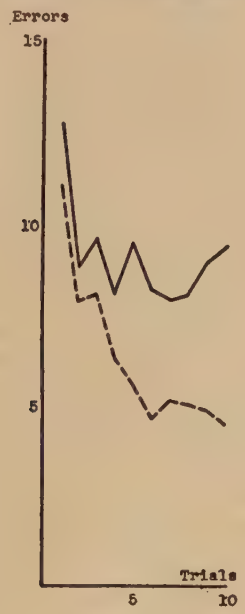

Fig. 4

——— Group 5

——— Group 6

Two new groups of subjects were obtained. Group V (10 Ss) received ten trials with the right foot followed by ten trials with the right hand. Group VI (11 Ss) received ten trials with the right hand. The averages of the two

groups are compared in Figure 4. Throughout the practice there is again a slight difference in favor of the transfer group. On the last three trials the difference between the two groups increases due to the fact that three out of the eleven Ss in Group VI showed a marked increase in errors on these trials. In the case of two of these Ss it is believed that the increase in error is due to a loss of interest. Reports obtained from them after the experiment confirm this hypothesis. The result of this further study of transfer from foot to hand supports the conclusion that practice with the foot has some slight effect on subsequent practice with the hand, although the effect seems to be less than in the case of transfer from hand to foot.

Transfer from Hand to Hand

In order to study transfer from one hand to the other, Group VI, which had already received ten trials practice with the right hand, using the device for controlling hand and wrist movements, was given ten trials with the left hand, using this same device. Another group (VII) was given ten trials with the left hand followed by ten with the right. With these two groups transfer from right to left hand and from left to right could be studied.

In this experiment a new condition was introduced. When the subjects changed from one hand to the other the position of the mirror was changed. When the right hand was used, the mirror was in its normal position at the subject's left, as in the previous experiments. In using the left hand, however, the mirror was placed in a similar position but to the right of the subject. The change probably has little or no effect on the experiment, for it merely causes a shift in absolute cues, such as nearness to, and distance from, the mirror of objects near the target. On the other hand, the posture of the subject is considerably changed, for he must hold his neck in opposite positions in the two cases. It is not believed that this change affected the results.

In Fig. 5 the averages of the two new groups for the left hand are shown. The graph shows that there is a slightly

greater inaccuracy for the left hand as contrasted with the results already obtained for the right. But again the general fact of transfer stands out. For Group VI, the transfer group is slightly better than VII, the controls.

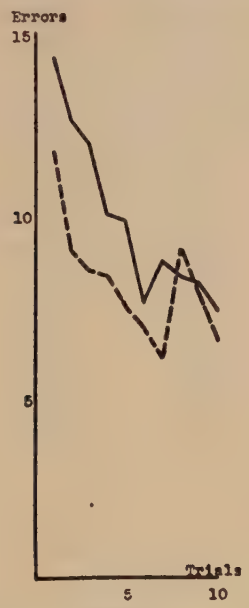

FIG. 5
——— Group 6
——— Group 7

Quite similar results are found in Fig. 6 where the curves of the two groups for the right hand are shown. These curves are not so smooth and regular as those previously shown; but Group VII, which in this case is the transfer group, presents a lower curve than VI.

In all the experiments reported here on transfer from one hand to the other, the differences between control and transfer subjects are small, and there is considerable overlapping between the control and transfer groups. Nevertheless, the fact that every group which has received previous practice with some other limb makes less error than its corresponding control-group is strong evidence for the existence of transfer.

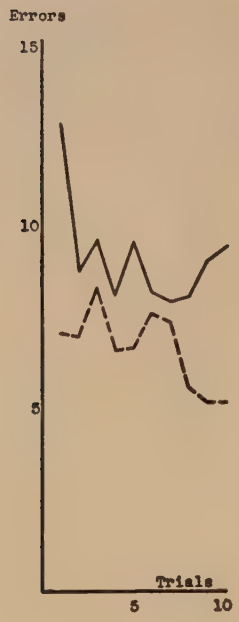

FIG. 6

——— Group 6
— — — Group 7

The results, shown graphically above, are summarized numerically in Table I. The average of each group, together

TABLE I

RIGHT FOOT

	Control Subjects					Transfer Subjects						
	Group 2		Group 5			Group 1		Group 3		Group 4		
Trial	Av.	M.v.	Av.	M.v.	Av.	Av.	M.v.	Av.	M.v.	Av.	M.v.	Av.
1....	19.1	5.9	20.5	8.8	19.7	8.6	2.9	9.2	4.3	9.2	6.0	9.0
2....	12.0	3.4	13.9	7.4	12.8	6.0	2.6	7.9	3.0	6.9	3.6	7.8
3....	11.8	5.4	10.9	3.7	11.4	6.6	2.2	7.3	1.5	6.4	3.2	8.0
4....	11.3	3.3	8.1	3.2	9.9	5.9	2.1	6.4	2.7	7.1	3.4	6.5
5....	9.2	5.6	8.3	2.9	8.8	5.7	2.5	7.6	3.7	5.8	2.9	6.3
6....	8.3	4.3	7.0	2.9	7.8	5.7	2.4	6.4	3.3	6.1	2.4	5.9
7....	9.1	4.4	5.7	1.5	7.7	5.2	2.3	5.6	2.2	5.4	2.3	5.4
8....	8.2	2.8	6.3	2.1	7.4	5.5	2.4	4.6	1.4	4.7	2.0	5.0
9....	7.0	2.2	5.6	1.7	6.4	5.8	2.1	4.6	1.8	4.9	1.8	5.1
10....	6.2	2.0	5.6	2.1	5.9	6.1	3.0	6.2	2.2	5.3	1.6	5.5

RIGHT HAND

	Control Subjects						Transfer			Control		Transfer			
	Group 1		Group 3		Group 4			Group 2		Group 6		Group 5		Group 7	
Trial	Av.	M.v.	Av.	M.v.	Av.	M.v.	Av.	Av.	M.v.	Av.	M.v.	Av.	M.v.	Av.	M.v.
1..	11.1	2.5	11.4	4.3	13.7	5.6	12.1	9.3	3.0	12.7	3.9	11.0	4.4	7.0	2.3
2..	9.5	2.5	9.6	3.7	9.9	4.4	9.7	7.7	2.4	8.7	3.9	7.8	3.2	6.9	2.2
3..	8.8	4.2	8.9	4.2	9.0	4.4	8.9	6.0	1.4	9.5	3.1	8.0	2.9	8.2	3.8
4..	7.1	2.0	7.8	2.6	8.8	3.8	7.9	6.0	1.9	8.0	3.3	6.2	1.8	6.5	2.4
5..	8.2	1.8	7.5	2.9	7.6	3.1	7.8	5.5	1.3	9.4	4.1	5.5	1.3	6.6	3.0
6..	7.2	2.2	8.3	4.4	7.0	2.1	7.5	4.7	1.4	8.1	4.0	4.6	1.4	7.5	5.1
7..	7.3	2.4	6.8	3.2	8.6	3.3	7.6	5.6	2.2	7.8	2.6	5.1	1.0	7.3	2.8
8..	6.6	2.5	5.1	1.5	6.1	2.6	5.9	5.6	2.2	8.0	4.3	5.0	1.8	5.5	2.7
9..	7.6	2.2	5.7	1.9	5.7	1.9	6.3	5.9	2.8	8.8	4.7	4.8	1.6	5.1	2.5
10..	6.9	2.9	5.6	1.8	7.1	2.4	6.5	4.7	1.8	9.3	5.4	4.4	1.1	5.1	1.7

LEFT HAND

	Control Subjects		Transfer Subjects	
	Group 7		Group 6	
Trial	Av.	M.v.	Av.	M.v.
1	14.3	4.2	11.7	3.4
2	12.6	4.8	9.0	2.9
3	11.9	4.5	8.4	2.4
4	10.0	2.3	8.3	2.0
5	9.8	2.8	7.5	2.4
6	7.6	1.9	6.9	1.3
7	8.7	2.9	6.1	1.2
8	8.3	3.0	9.0	2.8
9	8.1	3.0	7.7	2.3
10	7.3	1.7	6.5	2.6

with its mean variation, is shown for the first ten trials with each limb. In a few cases the average of several groups taken as a single unit is also given. Thus Groups II and V, both of which commenced with practice of the right foot, are combined into one average. Likewise Groups I, III and IV are combined for the right hand and foot. An examination of this table shows, as did the graphs, that in every case studied some transfer has been found. In order to facilitate comparison of the extent of transfer with practice by the various limbs, the percentage of error saved by each transfer-group in comparison with its corresponding control-group was calculated for the first ten trials. This calculation brings out merely the facts already noted that transfer is more effective from right hand to right foot than in any other case. The saving of groups transferred to the foot is reduced, however, to zero in the course of the first ten trials; whereas in the other cases the saving appears to last for an appreciably longer time, and in the one case where it has been studied it lasts for forty trials. No other differences in extent of transfer

can be obtained, as the averages are probably not sufficiently stable to admit accurate comparison of the various groups.

Discussion of Results

To explain transfer it is necessary to analyze the behavior of the subjects and to note the elements of practice that were common under the various conditions.

There were several factors which seemed to have no bearing on transfer and which may be readily disposed of. Thus the necessity for timing the hits in accord with the metronome and the necessity for returning to the starting position after every hit affected the accuracy of hitting. At the beginning of practice many subjects found it impossible to maintain the proper rhythm unless they attended closely to the speed of hitting. A few subjects likewise reported that the necessity to return to the starting position after every hit distracted their attention from accuracy and the reversing effect of the mirror. It has been shown by Schwarz [32] that in substituting a new habit for an old, a loss of attention causes the subject to revert to the old. In the present case the reversion would be to the normal habits of space-coördination and would result in inaccuracy of hitting. It is not believed, however, that this factor was of importance in transfer, for no evidence of improved rhythm or better adjustment to amplitude of swing was found in transferred subjects.

One other factor of importance in learning but of little or no importance in transfer was the position of the body with respect to the arm or leg. The bodily position was not controlled in the experiments, the subjects taking a position comfortable to them. Usually the position remained constant throughout any one sitting but sometimes changes occurred. The effect of change seemed to be temporarily to increase error unless the change brought the upper arm and shoulder into line with the target. In most cases shifting the body increased error and thus was probably one factor in causing variability. This factor had no apparent bearing on transfer, however.

Of more importance to the study of transfer were certain other factors. Chief among these was adjustment to the reversing effect of the mirror. At the beginning of practice the first hit was largely a matter of chance. The second, however, almost invariably carried the subject further away from the target because of the mirror-effect. The third hit might carry the subject still further away. Finally, a movement in the proper direction would be made. This was usually accomplished with a great deal of effort and in the hand-practice was frequently accompanied by movements of the whole body. A movement in the right direction was not,

[32] Untersuchungen zur Handlungs- und Affektspsychologie; iv. Ueber Rückfälligkeit bei Umgewöhnung; i Tl. Rückfalltendenz und Verwecklungsgefahr, Georg Schwarz, *Psychol. Forsch.* 1927, 9, 105.

of course, always successful in bringing the subject close to the target. Consequently a further correction was needed which might result in still another error of direction. Errors of direction dropped out rapidly in the course of the first few trials and occurred but rarely at the end of the first sitting.

Next to the difficulty in adjusting to the reversing effect of the mirror, the greatest difficulty was to correct by the proper amount. There was an almost universal tendency to overcorrect; *i.e.*, in correcting a previous error there was a tendency to go beyond the target to the other side. This source of inaccuracy was also eliminated almost completely in the course of the first sitting.

It is believed that these two factors are the most important in the experiment. An effort was made to observe whether errors of direction and overcorrections occurred more frequently in control than in transfer groups. To this end the experimenter counted the number of times that either appeared to occur in any trial. The accuracy of counting in this way is undoubtedly low; but it is significant that all transfer groups showed fewer errors of direction and fewer overcorrections than their corresponding control groups.

The elimination of errors of direction and of correction was due in part at least to the development of methods. At the beginning of practice a few subjects tried to use methods, but these were usually found ineffective. In the course of practice, methods were developed, however, and were used to eliminate the two sources of inaccuracy mentioned.

In adjusting to the reversing effect of the mirror several methods were reported. The majority of the subjects reporting methods found it best to correct an error kinæsthetically. That is, when a previous hit had been to one side of the target the subject tried to reverse the direction of his movement and go in the opposite direction on the next hit, the directions being determined kinæsthetically. Visual perception of errors played little part in this process, being used only to determine the existence and amount of errors but not their direction from the target.

A second method, used by a few subjects, was to try to go

further in the apparent direction of an error just previously made. Because of the reversing effect of the mirror this brought the subject back toward the target.

One further method was reported by two of our subjects, who observed that the side of the sheet of paper appearing further from the mirror was actually the side further away. That is, a hit at one side of the target might appear further from the mirror than the target itself and moving toward the mirror would correct in the proper direction. As this method was used by two subjects only, it was not very important in the experiment.

In order to overcome the tendency to overcorrect, a great many subjects reported that they made every corrective movement smaller than seemed necessary. Related to this method was the tendency (reported by nearly all subjects) to avoid trying to correct small errors. When a small error had been made, subjects found it better to refrain from any corrective movement and simply tried to repeat the previous movement.

One further factor that seemed of importance both in learning and in transfer was the initial nervousness and self-consciousness of some subjects. In many cases this was quite marked and was easily apparent to the experimenter. It is thought that this tended to decrease accuracy. After a few trials the nervous attitude disappeared and was replaced by an air of confidence. Usually, but not always, the confident attitude was carried over to practice with any other limb.

It was thought that an explanation of transfer might lie in the transfer of methods and in the elimination of the nervous attitude characteristic of so many subjects. Mere familiarity with the setting of the experiment might also be a factor in causing transfer. In order to test these various factors a new experiment was attempted in which the subjects were familiarized with the task and with the reversing effect of the mirror, and were given instructions as to the best methods to pursue in correcting errors.

On the spot usually occupied by the target a pendulum was set up. The screen was removed so that the pendulum

could be seen both directly and indirectly. The subjects were requested to watch the pendulum both directly and indirectly as it swung back and forth, alternating from one to the other method of watching. It was pointed out to them that the mirror reversed the direction of swing, causing the pendulum and its image to go in opposite directions, and that it also made the right side seem at the left and *vice versa.* After several minutes spent in watching the pendulum the subjects were shown their task by watching the experimenter go through the usual procedure of a trial with the right foot.

Following this demonstration the kinæsthetic method of correction was carefully explained to the subjects, who were requested to correct all errors by this method. They were also told to try to make smaller movements of correction than seemed necessary.

A third instruction was also given the subjects. Observation of the behavior of previous subjects had led to the conclusion that some of the errors were due to watching the foot as it approached the line. Subjects who did so would try to make corrective movements of the foot as they were hitting. This seemed to result in further error because the rhythm of hitting was lost, because it led to a jerky, uneven swing that was not conducive to accuracy and because errors of direction were frequently made. No subject reported this as a factor of importance, however, in the experiment. Consequently it may have been a mistake to instruct the new subjects to try not to correct on the forward swing.

The three points mentioned were explained carefully to the subjects and the experimenter made as certain as possible that the subject understood them. Ten trials of the foot were then given to each subject of the new group. There were ten men in this group. One of the ten consistently failed to follow instructions as to correcting errors of direction and stated that he found it impossible to do so. His results were extremely poor and he showed no improvement throughout the ten trials. The average of the other nine is compared in Fig. 7 with the average of all control subjects on the foot (Groups II and V) and with the average of all transfer subjects (Groups I, III and IV). It is shown that the instructed group is considerably better than the control group throughout the first ten trials. On the other hand, the new group does not show as great accuracy as the transfer

group for a few trials. The effect of the instructions and familiarity with the experiment has been to decrease considerably the early errors but not to the extent that they are decreased by previous practice with the right hand.

FIG. 7

——— Groups 1, 3, 4
——— Groups 2, 5
- - - - - Group 8

There are several possible explanations of the differences between the instructed and the transfer groups. It may be that other factors than those on which instruction was given are present in transfer. Thus it was noted above that directional correction was often accompanied by movements of the whole body in the direction of correction. It is obvious that movements of this sort might play a large rôle in transfer.

Similarly there might be movements of the eyes or head which would aid the subject in learning with the foot.

It may also be, however, that the difference between instructed and transferred groups is due to a lack of ability

FIG. 8

——— Groups 1, 3, 4,
——— Groups 2, 5
- - - - - Group 9

to follow instructions given in a merely verbal way. Nearly every subject in the instructed group reported that occasionally it was impossible for him to follow the instructions. Methods which had been learned by actual practice of the individual himself would probably be more successful than those given to him in verbal form.

It was also thought that the third instruction might have influenced the results. The instructed group may have received an advantage from this that the transfer groups did not have. Consequently a new group of subjects was obtained and given the same instructions and demonstration that had been given Group VIII, except that the instruction with respect to correcting while on the forward stroke was omitted.

The results of this further work are shown in Fig. 8, where Group IX (the new group) is compared with the control and transfer subjects on the foot. This curve represents the results of seven out of the nine subjects in the new group. Two subjects found it quite impossible to follow instructions and were omitted from consideration. The average of the other seven again falls between those of the control and transfer groups. It shows a slightly greater error than that previously given for Group VIII, the other instructed group.

The results of this work with the instructions support the hypothesis that carrying over previously learned methods to practice with a new limb accounts for a great deal of transferred learning. This conclusion is likewise supported by an observation on one subject of Group I who adopted a new method when changed from hand- to foot-practice. The curve for this subject was quite unlike that for the average of the transfer group and resembled closely that of the control group.

On the other hand, as stated above, it is impossible to say that transfer of method is the only factor of importance in transfer. The instructed groups do not show as great accuracy as the transfer groups, and it is not known to what this difference is due.

Summary and Conclusions

It has been shown that in the mirror-accuracy experiment a transfer of learning from right hand to right foot takes place. The effect of previous practice with the hand is to increase considerably the initial accuracy of the foot and to save the equivalent of about six trials. It has also been shown that

varying the amount of hand-practice from ten to sixty trials has no observable effect on transfer to the foot. There are also indications that transfer does not occur if the first fall of the learning curve of the hand has not been completed.

Transfer from right foot to right hand also occurs. It seems to be less in amount but effective over a longer period than transfer from hand to foot. Likewise a slight transfer effect is observable from one hand to the other.

The explanation of this form of transfer probably lies, in part at least, in the transfer of methods which having been learned for one part of the body are carried over to practice with some other part. Mere familiarity with the setting of the experiment is probably also important in transfer.

(Manuscript received June 11, 1928)

Accepted by the Department of Psychology, May, 1928

LANCASTER PRESS, INC.
LANCASTER, PA.